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## 1990-91 PROJECT SUMMARIES

### GEORGIA INSTITUTE OF TECHNOLOGY

#### A LUNAR SURFACE VEHICLE MODEL

To facilitate the future exploration and possible colonization of the Moon, a remotely operated vehicle is needed so that materials and supplies can be easily transported. This vehicle must be able to pick up a specified payload, transport it over the rough lunar surface, and then unload the payload at a desired location. We have designed a model of such a vehicle to permit the evaluation of its performance in an Earth environment. The layout of the model consists of a six-wheel drive, four-wheel steering, remote-radio-controlled vehicle.

The chassis design consists of an aluminum two-tier arrangement to provide adequate space for the components and systems of the vehicle. The lower tier contains the powertrain components while the upper tier contains the steering mechanism, the speed controller, and the payload lifting mechanism.

The vehicle's independent suspension uses a nylon fiber reinforced composite upper and lower control arm for each wheel and a plexiglass transverse leaf spring for each axle. The upper control arm contains a turn buckle to allow for camber adjustment of each wheel. The leaf spring is a simple design that has an adjustable spring rate.

The powertrain consists of a 20,000-rpm, 0.16-hp, DC motor powered by a 7.2-V, six-cell battery pack. The motor is controlled by a resistor-type speed controller with variable braking and reverse, and provides power to a 65:1 gear reduction unit that, in turn, powers three belt drives for the three differentials. The differentials are of a limited slip "ball" type used in model RC cars. This type of differential will allow better traction in loose soil. The differentials provide torque to the driveshafts, which are connected with universal joints at both ends.

The wheels for the vehicle are made of polystyrene foam for weight optimization and have an ellipsoidal shape. A custom, paddle-type tread design is epoxied to the wheel before the outer surface of the wheel is dipped in a rubber compound to give a uniform coating. The ellipsoidal shape provides a large contact patch, which in sand gives maximum traction and also allows point contact on hard surfaces, which requires less steering force.

The steering system uses the Davis design, which allows for the correct turning angles of the inside and outside wheels such that each wheel has the same center of rotation giving no "scrub." A maximum inside wheel turning angle of 30° requires an outside wheel turning angle of 16°. These angles provide for a small turning radius of 23.3 in. The design uses a linear servo-controlled moving slider bar connecting two slotted members, one for each wheel. The movement of the slider bar causes the slotted members to rotate through different

angles of rotation giving the necessary wheel angles. The vehicle design uses four-bar linkage to connect the rear steering angle with the front steering angle with the aid of two spur gears to change the angle of rotation from rear to front.

The payload is an aluminum spool with a mass of 0.5 kg. The bottom lip of the spool contains more mass than the upper lip to prevent it from being tipped over easily. The lift mechanism consists of a chassis-mounted track, a sled that slides along the track, a pair of forks hinged to the front of the sled, a servo mounted to the chassis underneath the track, and a lifting arm mounted to the servo. The arm is connected to the forks through a cable; the end of this cable slides on the arm to prevent binding. The lift operates by approaching the payload with the sled in its lowest position with forks extended. After the payload is positioned within the forks, the lift arm, riding in a vertical slot through the center of the sled, pulls the forks into a vertical position so that the payload then rests within a round depression in the face of the sled. At this point, the lift arm makes contact with the end of the slot. A roller is mounted at the point of contact to minimize friction. The lift arm now pushes the sled up along the track, to a horizontal position behind the front wheels. The payload is held by gravity within the depression in the top of the sled. To unload the payload, the lift arm pushes the sled back down the track, then lowers the forks down to vertical position such that the payload is resting on the ground. The vehicle then backs away from the payload.

#### LUNAR LOADER/TRANSPORTER

With the increasing possibility of inhabiting the Moon, researchers are exploring feasible modes of lunar transportation. This paper researches one such transportation vehicle. The lifting mechanism offers several degrees of freedom. The additional degrees of freedom assist the operator in the loading and unloading of cargo in most regions of the Moon terrain. The vehicle's tires and body were both designed to efficiently operate on the Moon's rocky surface. The lunar transporter, specified within, may offer researchers some answers and incentives for future space exploration.

#### TRENCHING AND CABLE-LAYING DEVICE FOR THE LUNAR SURFACE

This paper details the design of a trenching and cable-laying machine for use on the Moon. Lunar bases will require exterior cables for power and communication. Burying these cables 1 m below the lunar surface shields the cables from radiation, meteorites, and surface traffic. The cable-laying device described

in the paper excavates a narrow trench 1 m in depth and lays a cable (2.5 cm maximum diameter) over a distance of 1 km. The trench is formed by a vibratory dual-plow system. The first plow digs a trench 0.5 m in depth and 10 cm wide, and the second plow deepens the trench to a depth of 1 m and width of 5 cm. The two-pass configuration of the plow greatly reduces the draw-bar force of the plowing action. Additionally, each plow blade is vibrated to further decrease the force needed to shear the soil. The drive system for the cable-laying plow consists of an auger mechanism. The auger drive system overcomes the traction problems associated with plowing in the low-gravity environment of the Moon. Since the traction is not gained through the weight of the vehicle itself, pulling the plow by the auger allows the cable-laying machine to remain small and light-weight.

#### **A LUNAR VEHICLE SYSTEM FOR HABITAT TRANSPORT AND PLACEMENT**

This paper addresses the need for a piece of machinery to unload, transport, and place a lunar habitat on the Moon's surface. Since NASA intends to carry out mining operations, as well as prepare the Moon for future colonization, habitats are needed to accommodate the astronauts on the extended lunar missions. Therefore, NASA must find a way to relocate these habitats once they are delivered to the Moon by a lunar lander. The design solution recommended by this paper is the use of two track vehicles containing scissors-lifts with cradles located on top. Each vehicle will be aligned under one end of the habitat. The scissors-lift will extend and the cradle will be adjusted to line up with the coupling neck of the habitat. Each scissors-cradle

mechanism will extend to a height in excess of 10 m to lift the habitat off the lander. The vehicles will be turned parallel to one another and moved until the habitat is clear of the lander. The scissors-cradle mechanism will then collapse, and the vehicles will be aligned and driven to the desired habitat location. At this point the scissors-cradle mechanism will fully compress to a vehicle height of 2.5 m, placing the habitat on the lunar surface. The vehicle will then drive out from under the habitat. This design solution takes into account power requirements, torque requirements, and the dimensions of the lander and shuttle bay.

#### **LUNAR STORAGE FACILITY**

Before the construction of a manned lunar base can begin, a storage facility must be set up. The purpose of this facility will be to store electronic equipment and small containers of other miscellaneous equipment, while protecting it from radiation. The goal of this project was to assess the need and then to find the optimal design by considering many performance objectives and constraints.

The proposed lunar storage facility is self-erecting, uses material (regolith) from the lunar surface, and can store objects of variable geometry, up to 3 m high. During shipment in the space shuttle cargo bay, the shed will be reduced to a basic cylinder shape whose outer dimensions will be 4 m in diameter by 15 m in length. Set-up of this shed will consist mainly of releasing a locking mechanism, after which the release of potential energy will cause the shed to erect itself. Radiation protection will be provided by filling an outer bladder with 2 m of regolith using a regolith slinging mechanism.